Water Demand Forecast Methodology for California Water Planning Areas - Work Plan and Model Review

Final

Prepared for the Cal-Fed Bay Delta Program

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by

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1.0 Introduction

Member agencies of the California Bay-Delta Authority (CBDA, formerly CALFED) have an interest in identifying models that may be used in water resource planning within the State of California. This technical memorandum establishes a work plan for developing a water demand forecasting model. The work plan developed from this review proposes a systematic methodology for forecasting municipal and industrial (residential and nonresidential, public and self-supplied) water demand throughout the state (by planning area or county) based on an assessment and analysis of available data. The model review includes a description of data requirements and outputs to meet the needs of the CBDA Common Assumptions efforts.

Selection of a water demand forecast methodology is a function of three primary criteria: planning objective, available data and available resources. The planning objective for development of a water demand forecast defines the level of detail needed by the water resource decision-makers who will utilize the water demand forecast information. Members of the CBDA need a reliable water demand forecast, as well as a uniform methodology for estimating water demand through the state. The level of detail does not require the development of water demand forecasts for each water provider in the state. Thus, the level of analysis may be at a planning area or county level. It is understood that such forecasts may differ from local service area demand forecasts prepared by individual water providers.

Furthermore, whereas previous state water plans have been a single-point forecast based on a single set of assumptions, the current update of the state water plan calls for development of several possible alternatives for water use, water supply and water management. A number of factors that affect water demand have been identified by stakeholders, including:

- Population
- Population density
- Population distribution
- Per capita income
- Commercial activity and mix
- Industrial activity and mix
- Naturally occurring conservation
- Urban water use efficiency from implementation of Best Management Practices (BMPs)
- Climate change

Thus, model selection must consider the planning objective to permit the development of alternative water demand scenarios through variation of factors that affect water demand.

Selection of a water demand forecast methodology is driven in part by the data that can be made available through primary and secondary collection efforts. Time and money will be required to identify and compile existing (secondary) data that can support the forecasting methodology and additional costs will be incurred to generate new (primary) information, if considered necessary. This review provides an assessment of the data readily available for use in developing a water demand forecast. The proposed options for the forecast methodology are designed in consideration of readily available data and identify additional data requirements where warranted.

Note that the Department of Water Resources (DWR) has licensed copies of the IWR-MAIN Water Demand Management Suite software for use in developing water demand forecasts. Unlike previous versions of the IWR-MAIN software that contained specific water demand models, the current version of the software requires the user to select and specify a water forecasting methodology. Thus, DWR staff must select an appropriate water demand forecasting methodology before using the IWR-MAIN software to manage data inputs and generate water demand forecasts.

2.0 Model Methodology Options

2.1 Residential and Nonresidential Water Demand Models

Broadly defined the methodological options are:

- Trend extrapolation
- Per capita method
- Number of unit times a per unit use approach, where the per unit use is fixed
- Number of unit times a per unit use approach, where the per unit use is variable and related to influencing factors

The first two methods do not incorporate information regarding factors that influence water demand. The forecasting methodologies discussed below follow the general format of number of unit times a per unit use. Each methodology examines a different approach to determining the per unit use element.

Each of these methodologies follows the approach:

$$Q_{c,m,y} = q_{c,m,y} \bullet N_y$$

where:

Q = monthly water use
q = per unit use
N = number of units
c = customer class
m = month
y = year

Thus, the projected number of unit times the estimated water use per unit yields the estimate of water use for the given customer class (e.g., single-family, commercial, etc.). The number of units (N) may be defined for any geographic level, such as planning area or county, depending upon defined forecast geography and the availability of data. The per unit value of (q) is estimated in one of the following methods.

2.1.1 Average Rate of Use

This approach assumes an average per unit use value of (q) for a defined geography and time period, and is held constant throughout the forecast period. It follows the general form:

$$q_{c,m,l} = (Q_{c,m}/N_c)$$

where:

q = average use per account
c = customer class
m = month
l = location (i.e., county)
u = utility
Q = water consumption
N = number of accounts

Note that the values for Q and N for a given location (l) may be derived from multiple reporting utilities and that each reporting utility may provide data for multiple years. Thus, an average rate of use is determined as follows.

The utility data must be in matched sets, that is for each reported water delivery ($Q_{u,c,m,y}$) there must be a corresponding number of accounts ($N_{u,c,y}$). For each utility, the water delivery values are summed for all reporting years of a given month for a given customer class (e.g., sum of all January single-family consumption across reported years). Similarly, the number of accounts for the customer class is summed (e.g., sum of single-family accounts across reported years). These two sums are divided to determine the average rate of use per account for the month for the utility for the customer class ($q_{u,c,m}$).

In addition, the sum of accounts by utility and customer class is divided by the number of reporting years to determine the average number of accounts. The average rate of use ($q_{u,c,m}$) is weighted across utilities within the location (l) (e.g., county) by the average number of accounts for the customer class.

The average rate of use by class and county can be developed with the data contained in the Public Water Supply Survey (PWSS) database (discussed below). The methodology requires the projected number of accounts by county (or other location definition) in order to estimate future water demand. Data for the reporting utilities in the PWSS contains number of accounts by customer class and population served. The population served data may need to be verified. The number of accounts by customer class and population served can be added across utilities within the location (e.g., county) and then divided to estimate the average ratio of accounts to population for each customer class. This average ratio of accounts to population can be multiplied by the projected population for the county to derive the projected number of accounts for each customer class in future years.

2.1.2 Disaggregate Factor Forecast

The disaggregate factor forecast allows an adjustment to the per unit use factor and follows the general form:

$$Q=N*q$$

where:

$$q_{c,m,y} = (Q_b/N_b)_{c,m}\ (X_{1f}/X_{1b})^{\beta_1}{}_{c,m}\ (X_{2f}/X_{2b})^{\beta_2}{}_{c,m} \ldots\ (X_{nf}/X_{nb})^{\beta_n}{}_{c,m}$$

and:

q = adjusted per unit use
c = customer class
m = month
y = year (b = base period; f = future year)
Q_b = base year per unit use
N_b = counting unit (e.g., account, housing unit, population, etc.)
X_b = base year factor variable
X_f = projected factor variable
β = elasticity

Unlike the functional per unit use and functional population approaches described below, factor variables are not determined by regression analysis. The factor forecast can be developed from base year values for water use data (Q and N) and base year and future year values for the factor variables. Factor variables can include median household income, persons per household, maximum temperature, precipitation, cooling degree days, housing density, marginal price, etc.

The elasticities for the factor variables may be selected from a literature review of water demand models. The result of this model is a per unit use (q) adjusted, or normalized, for variations in selected factors that affect water demand.

2.1.3 Functional Per Unit

The functional per unit use model estimates values of per unit use and follows the general form:

$$Q=N*q$$

where:

$$q_{u,c,m,y} = \alpha\ (X_1^{\beta_1} X_2^{\beta_2} \ldots X_n^{\beta_n})_{u,c,m,y}$$

and:

q = per unit use
u = utility
c = customer class
m = month
y = year
α = intercept
X = explanatory variable
β = elasticity

Explanatory variables are specified based on a prior knowledge and data availability and elasticities are estimated using regression analysis. These can include median household income, persons per household, maximum temperature, precipitation, cooling degree days, marginal price, employment to housing ratios, industrial group employment to total employment ratios, etc. The per unit (i.e., account) use data (q) from the PWSS provides an excellent array of water use observations. Corresponding values for explanatory variables may be obtained from weather stations and Census data at the municipal or Census Designated Place level. The regression analysis would provide a statistical model for estimating the average rate of water use (q) from a given set of explanatory variables.

Projected values for each explanatory variable are required to develop the estimated future per unit use values for each location (e.g., county or planning area). Projected values for the number of units (N) are also required.

This approach may be constrained by the absence of, or inability to project, reliable explanatory variable values. Also, the counting unit data must be defined in the same units as the customer class units (N). For example, if the per unit use (q) is defined as gallons per account, then N must be defined as number of accounts. Alternatively, the per unit use may defined as water use per demographic unit, such as housing unit or employment, and the customer class unit (N) would be defined as the same unit.

This approach requires a commitment of resources for data collection and statistical modeling of the database, in addition to the development of the forecasting procedures.

2.1.4 Functional Population

The functional population model follows the general form:

$$Q = POP * gpcd$$

where:

$$gpcd_{c,m,y} = \alpha \, (X_1^{\beta_1} X_2^{\beta_2} \ldots X_n^{\beta_n})_{c,m,y}$$

and:

gpcd = gallons per capita day
u = utility
m = month
y = year
α = *intercept*
X = explanatory variable
β = *elasticity*

Significant explanatory variables are determined by regression analysis. These can include median household income, persons per household, maximum temperature, precipitation, cooling degree days, marginal price, employment to housing ratios, industrial group employment to total employment ratios, customer class account to total account ratios, etc.

Unlike the functional per unit use model, this approach is not constrained by the absence of reliable account or other counting unit data. The unit variable is population. It can, however, be constrained by the absence of, or inability to project, reliable future values for the explanatory variables.

As with the functional per unit use model, this approach requires the data collection and statistical modeling effort in addition to the demand forecasting procedures.

2.2 Other (Unaccounted-For) Water Use

Estimates of unmetered/unaccounted-for water use should be included in estimates of total municipal and industrial water demand. Estimated percent unaccounted water may be derived from the PWSS database which contains water production and water delivery data for a large sample of utilities. An average rate of unaccounted-for use may be determined and applied to the estimated Municipal and Industrial (M&I) water demand for each planning area or county. A weighted average rate of unaccounted-for use may be calculated for each geography that weights known unaccounted-for rates (i.e., utility-served areas) and an assumed unaccounted-for use rate for remaining water users within the geography. For example, the unaccounted-for rate of use for self-supplied users may be near zero.

2.3 Conservation Effects

The IWR-MAIN Water Demand Management Suite software has a Conservation Manager that allows the estimation of water demands by end use, and permits the evaluation of the impact of conservation on water use. The structural end use equation for estimating water use for each end use is represented by a single formula of the following form:

$$q_e = [(M_1S_1 + M_2S_2 + M_3S_3) * U_N] * A_N$$

where:

q_e = *quantity of water for end use e, gpd/unit*

M_{1-3} = *mechanical efficiency parameters (e.g., volume per use, flow rate per minute)*

S_{1-3} = *fractions of end uses in the sector that are nonconserving, conserving and ultraconserving*

U_N	=	*intensity of usage parameter (e.g., flushes per day/unit, minutes of use per day/unit)*
A_N	=	*fraction of units in which end use e is present; value may be in the range of 0 to 1*

and:

e	=	*denotes specified end uses*
N	=	*denotes normal use or nondrought/nonemergency*
1-3	=	*denotes the nonconserving$^{(1)}$, conserving$^{(2)}$ and ultraconserving$^{(3)}$ classes of each end use*

Long-term conservation savings are achieved by increasing the fractions S_2 and S_3. The water customers (counting units) and the end uses they represent, would be shifted from lower to higher classes of efficiency. Effective long-term conservation is accomplished by moving customers from a low-efficiency level to a level of higher efficiency. A level refers to a group of customers with nonconserving, conserving or ultraconserving end uses within a sector. The quantifiable effect of the conservation program is accounted for directly by the numerical shift in the levels and the resultant change in the fractions of nonconserving (S_1), conserving (S_2) and ultraconserving (S_3) units. The consumption that would have occurred without changes in the base year distribution of fractions of $S_{1\text{-}3}$ serves as a basis from which the savings are measured.

For the DWR statewide application, two aspects of potential water conservation savings will need to be considered: passive savings and active savings. The "passive" savings represent shifts from less efficient to more efficient levels of end uses that are expected to occur naturally over time as technology continually improves. This is defined as the fraction of nonconserving, conserving and ultraconserving groups of S_1, S_2 and S_3, respectively and their mechanical parameters of M_1, M_2 and M_3. The natural shifts toward higher efficiency levels (often accelerated by plumbing codes and the 1992 Energy Policy Act standards) are determined using four rates of movement. These rates describe the form in which these shifts take place and additionally show the rate at which they occur. Variables and notations used in the calculation of passive savings are defined as:

CR	=	compliance rate (which allocates end uses in newly constructed units into the highest efficiency class with the total number of units designated as N_3 and the noncomplying units assigned to N_2)
NR_2	=	remodeling replacement of conserving M_2 end uses (due to wear, remodeling, demolition) with ultraconserving end uses M_3 by shifting a portion of N_2 into N_3

NR_1 = remodeling replacement of nonconserving end uses M_1 (due to wear, remodeling, demolition) with ultraconserving end uses M_3 by shifting a portion of N_1 into N_3

RR = rate of retrofitting M_1 to M_2 (customer initiated retrofits)

"Active" conservation savings (including the BMPs, in section 3.4) occur when units are shifted from lower levels of water efficiency to higher levels for a given end use as a result of a utility-sponsored (i.e., active) conservation program.

3.0 Assessment of Available Data

This section provides a review of data availability for information (i.e., variables) important in the development of a water demand model and forecast. Availability of these data can affect the selection of a water demand forecasting methodology.

3.1 Water Use Data

3.1.1 Public Water Supply Survey (PWSS) Database

The Department of Water Resources Public Water Supply Survey (DWR PWSS) database contains calendar year data compiled from 1994-2001 annual surveys of subsets of California utilities. The surveys are voluntary and nonrandom. These data consist of numbers of connections, monthly production, and monthly metered potable water deliveries for customer classes including single-family residential, multifamily residential, commercial/institutional, industrial, large landscape irrigation, and other.

The database can be used to provide average water consumption per account on a monthly basis by customer class for a sample of utilities over a seven-year time period. Preliminary queries of the database indicate that data for both number of accounts and monthly consumption are available from utilities representing most but not all of the counties in the state. Those counties not represented in the PWSS appear to be among the relatively small and less populated counties.

This database provides a wealth of utility level water consumption data with a diverse representation of utilities from across the state.

3.1.2 USGS Estimates

USGS water use estimates are available online for 1985, 1990, and 1995. The California water use estimate data for 1985 and 1990 are available at the county, water-resources subregion, water-resources accounting units, and water-resources cataloging units; 1995 data is offered at the county and watershed levels. The 1985 and 1990 water use estimates are available for public supply, commercial, domestic, industrial, thermoelectric power (electric, fossil fuel, geothermal, and nuclear), livestock, irrigation, hydroelectric power, sewage treatment, reservoir evaporation, and total water use. The 1995 data differs slightly in the category breakdowns. The thermoelectric power and the livestock categories are aggregated a bit differently, but by and large the data sets contain the same data categories.

The methodology behind this data is not published, although some general background is available. For example, public supply estimates are derived from annual surveys of public water suppliers (i.e., the DWR PWSS data). The surveys provide monthly production data from Surface Water, Groundwater, Purchased, and Reclaimed sources and monthly deliveries to single-family and multifamily residential, commercial, industrial, irrigation and other water users. This is supplemented with data from the California

Department of Health Services (Personal Communication, Bill Templin USGS, 6/2003).

"For 1995 and 2000 the Pacific Institute in Oakland estimated commercial and industrial water use with coefficients developed from the latest DWR Industrial survey supplemented with employment data from the California Employment Development Department" (Personal Communication, Bill Templin USGS, 6/2003).

The industrial estimate was based on a small survey in 1990 while the 1995 estimate was more complete. The 1995 estimate used coefficients from a number of sources, including the MWD MAIN forecasting system of models (Personal Communication, Bill Templin USGS, 6/2003).

3.2 Demographic Data

The Department of Water Resources prepared a summary of demographic data availability for the State of California. This summary is included as Table 3-1.

TABLE 3-1
CALIFORNIA DEMOGRAPHIC DATA AVAILABILITY

DEMOGRAPHIC	SUBJECT	GEOGRAPHY	AVAILABLE DATA	REPORT NAME	AGENCY	WEBSITE
Population	Total Population	Detailed Analysis Unit (DAU) by County (which can be aggregated to Planning Areas (PAs) to Hydrologic Regions to Statewide)	Total Population by DAU by County for 1998, 2000, 2001, and 2030.	**Ag Urban Intranet Database - Population Table (Marla Hambright)**	DWR Statewide Planning	scotth@water.ca.gov
		State/County/City	Total Population	**E-1 City/County Population Estimates with Annual Percent Change, January 1, 2002 and 2003**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/E-1text.htm
		County	Total Population, Percent Change, and Components of Change	**E-2 County Population Estimates and Components of Change, July 1, 2001-2002, with Historical 2000 and 2001 Estimates**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/E-2text.htm
		State/County/City	Total Population 2000-2003	**E-4 Population Estimates for Cities, Counties, and the State 2001-2003 with 2000 DRU Benchmark**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/Hist_E-4.xls
		County	Updated and revised historical (1990-1999) county total population, percent change, and components of change	**E-6 Updated Revised Historical County Population Estimates and Components of Change - July 1, 1990-1999**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/E-6_UPDTD_90-99.HTM
		County	2000 estimated population and the projected population for 2005, 2010, 2015, and 2020	**Interim County Population Projections**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/P1.doc
		County	County Population projections with age, sex, race/ethnic detail 1990-2040 in 10 year increments (from 1990 data)	**County Population Projections**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/Proj_age.htm
		State/County/Census Tract/Block Group/Block/Place	Total Pop (P1)	**2000 Summary File 1 (SF1)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
		State/County/Census Tract/Block Group/Block/Place	Total Pop (P1)	**2000 Summary File 3 (SF3)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
		City	Population, Income, Water Rate and Employment 1970-1995 and projected 1996-2020 for these areas: East Bay MUD, Fresno, L.A., Marin MUD, Sacramento, San Bernardino, San Diego, San Francisco, Santa Barbara and the CPI 1970-2020.	**Population, Income, Water Rate, and Employment for Selected CA Cities (Richard Le)**	DWR Statewide Planning	mwilber@water.ca.gov
	Persons per Household	State/County/City	Persons per Household (Benchmark 2000, revised 2001, 2002, and 2003)	**E-5 City/County/State Population and Housing Estimates**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/E5a.xls
Housing	Housing Units	State/County/Census Tract/Block Group/Block/Place	Total Housing Units (H1)	**2000 Summary File 1 (SF1)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
		State/County/Census Tract/Block Group/Block/Place	Total Housing Units (H1)	**2000 Summary File 3 (SF3)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
	Units in Structure	State/County/Census Tract/Block Group/Block/Place	Units in Structure (H30)	**2000 Summary File 3 (SF3)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
		State/County/City	Single (detached and attached), Multiple (2 to 4, 5+, mobile homes), Occupied, Vacant (Benchmark 2000, revised 2001, 2002 and 2003)	**E-5 City/County/State Population and Housing Estimates**	CA DOF (Dept. of Finance	http://www.dof.ca.gov/HTML/DEMOGRAP/E5a.xls
	Year Built	State/County/City/CDP (Census Designated Place)	Year Structure Built (H34)	**2000 Summary File 3 (SF3)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
	Density (units per acre)					

TABLE 3-1
CALIFORNIA DEMOGRAPHIC DATA AVAILABILITY (CONTINUED)

DEMOGRAPHIC	SUBJECT	GEOGRAPHY	AVAILABLE DATA	REPORT NAME	AGENCY	WEBSITE
Income	**Median Income**	State/County/City/CDP (Census Designated Place)	Median Household Income in 1999 dollars (P53)	**2000 Summary File 3 (SF3)**	US Census Bureau	http://factfinder.census.gov/servlet/BasicFactsServlet
		State	Median Household Income in constant 1996 dollars, updated 3/2003	**Median Household and Family Income, CA (Annual from 1959)**	CA DOF (Dept. of Finance)	http://www.dof.ca.gov/HTML/FS_DATA/LatestEconData/Data/Income/Bbmedian.xls
		City	Population, Income, Water Rate and Employment 1970-1995 and projected 1996-2020 for these areas: East Bay MUD, Fresno, L.A., Marin MUD, Sacramento, San Bernardino, San Diego, San Francisco, Santa Barbara, and the CPI 1970-2020.	**Population, Income, Water Rate, and Employment for Selected CA Cities (Richard Le)**	DWR Statewide Planning	mwilber@water.ca.gov
Employment	**Employment**	City	Population, Income, Water Rate, and Employment 1970-1995 and projected 1996-2020 for these areas: East Bay MUD, Fresno, L.A., Marin MUD, Sacramento, San Bernardino, San Diego, San Francisco, Santa Barbara, and the CPI 1970-2020.	**Population, Income, Water Rate, and Employment for Selected CA Cities (Richard Le)**	DWR Statewide Planning	mwilber@water.ca.gov
		State	Industry Employment & Labor Force Annual Average Summary for California 1992, 1994, 1998, 2000, 2001, projected 2010, 2020, 2030. Raw data from EDD for years 1983-2001.	**California Annual Employment Data 1992-2000 (Monique Wilber based on R. Le's methodology)**	DWR Statewide Planning	mwilber@water.ca.gov
		State/County/MSA	Civilian Employment by NAICS code (ex. 10-113300) and name (ex. Logging) divided into 372 classifications. 1990-2002 (historical data also available from 1983 at same website)	**Industry Employment & Labor Force by Annual Average (Employment by Industry Data)**	California Employment Development Department, Labor Market Information	http://www.calmis.ca.gov/htmlfile/subject/indtable.htm#table
Climate	**Average Daily Max Temp (Normals & Actual)**	State/Individual Stations	1971-2000 NCDC Normals- Period of Record Monthly Climate Summaries, Historical Climate Information-Period of Record-Temp. Average Max Temp (ex. 1948-2003)	**Monthly Average Maximum Temperature**	Western Regional Climate Center (WRCC)	http://www.wrcc.dri.edu/climsum.html
	Precipitation (Normals & Actual)	State/Individual Stations	1971-2000 NCDC Normals, Monthly Precip. Listing-Monthly Totals	**Monthly Total Precipitation**	Western Regional Climate Center (WRCC)	http://www.wrcc.dri.edu/climsum.html
	Cooling Degree Days (Normals)	State/Individual Stations	1971-2000 NCDC Monthly Normals	**1971-2000 NCDC Monthly Normals**	Western Regional Climate Center (WRCC)	http://www.wrcc.dri.edu/climsum.html
	Cooling Degree Days (Actual)	State/Individual Stations	Actual Year Monthly Cooling Degree Days	**Monthly Total Cooling Degree Days for year _____**	Jim Ashby of WRCC	jawrcc@dri.edu

3.2.1 Base Year (Historical)

3.2.1.1 *Population*

Total population data are available for Detailed Analysis Units (DAU) by county for the years 1998, 2000, 2001, and 2030, which was prepared by DWR staff. These data can be further aggregated to Planning Areas, Hydrologic Regions, and Statewide.

The E-1 City/County Population Estimates with Annual Percent Change and the E-2 County Population Estimates and Components of Change provide the data used for the years after the 2000 Census. The E-6 Revised Historical County Population Estimates and Components of Change provide the data for the years 1990-1999. All of these data are available from the California Department of Finance (CA DOF).

State, County, Census County Division, Census Tract, Block Group, Block and Place level data are available through the 2000 Census SF1 and SF3 cd/dvd datasets. Data are also available from the U.S. Census Bureau through the "American Factfinder" web page.

3.2.1.2 *Housing*

Housing data are available from a few of the sources identified as sources for population data. Census Bureau's SF1 and SF3 data sets are available at all census geography levels. CA DOF's E-5 City/County Population and Housing Estimates are available for cities and counties only (it is not recommended to use the E-5 <u>Population</u> numbers, as they are not updated). Another source for housing data is the Census Bureau's 108th Congressional District summary file, which contains population, housing units, area, and housing density for the year 2000. These data are available at State/County/City/Census Designated Place (CDP) levels.

3.2.1.3 *Income*

The Census Bureau's SF3 file contains Median Household Income at the State, County, City, and CDP levels. These data are available on cd/dvd and the American Factfinder web page. The CA DOF offers state level Median Household Income 1959-2001. These data are held constant at 1996 price levels (i.e., expressed in 1996 dollars). DWR staff has compiled county level income data for 1969, 1979, and 1989. DWR staff projected income to 2000, 2010, 2020, and 2030.

3.2.1.4 *Employment*

The Department of Water Resources Statewide Planning offers city level employment data through their dataset titled Population, Income, Water Rate, and Employment for Selected CA Cities. Selected cities include: East Bay MUD, Fresno, L.A., Marin MUD, Sacramento, San Bernardino, San Diego, San Francisco, and Santa Barbara.

State level employment data are available from DWR staff based on California Employment Development Department (CA EDD) data from 1992-

2001 with decennial projections in 2010, 2020, and 2030. The 1992-2001 data include industry descriptions and North American Industry Classification System (NAICS) codes. The projections are aggregated into industrial, commercial, services and government classifications.

County level employment data are also available from http://www.calmis.ca.gov/htmlfile/subject/indtable.htm#table. These data contain two-digit level NAICS aggregate data from 1990-2002 at the county level.

3.2.2 Projections

3.2.2.1 *Population*

The CA DOF offers county population projections. The report titled Interim County Population Projections contains estimated population data for 2000 and projections for 2005, 2010, 2015 and 2020 and is based on their 1998 projections. The CA DOF provided DWR with a 2030 projection.

The Department of Water Resources staff uses regional Council of Government (COG) data as a guide to disaggregate CA DOF projections at a sub-county level.

3.2.2.2 *Housing*

A source for state or county level housing projections has not been identified.

3.2.2.3 *Income*

The Department of Water Resources has county level income projections for 2000, 2010, 2020, and 2030.

3.2.2.4 *Employment*

The Department of Water Resources has state level employment projections for 2010, 2020, and 2030. In addition, county level employment is projected for industrial, commercial, services, and government sectors.

3.3 Weather Data

Weather data are available from the Western Regional Climate Center (WRCC). The WRCC website has data for various parameters such as temperature, precipitation and cooling degree days (normals) for individual weather stations throughout California. Monthly observed values are available for monthly average maximum temperature and monthly total precipitation from 1971-2000. Monthly cooling degree day normals (long-term averages) are also available.

3.4 Conservation BMP Data

In the State of California, the California Urban Water Conservation Council (CUWCC) is the guiding agency for the promotion of water conservation activities. The CUWCC was created to "increase efficient water use statewide through partnerships among urban water agencies, public interest organizations and private entities. The CUWCCs goal is to integrate urban water conservation BMPs into the planning and management of California's water resources." The primary mechanism for the promotion of urban water conservation practices is through the "Memorandum of Understanding (MOU)" by which signatories to the MOU agree to the implementation of BMPs. Currently, there are about 170 wholesale and retail water providers who are signatories to the MOU. Currently, there are 14 specified BMPs as part of the MOU:

- BMP 1: Water Survey Programs for Single-Family and Multifamily Residential Customers
- BMP 2: Residential Plumbing Retrofit
- BMP 3: System Water Audits, Leak Detection and Repair
- BMP 4: Metering with Commodity Rates for all New Connections and Retrofit of Existing Connections
- BMP 5: Large Landscape Conservation Programs and Incentives
- BMP 6: High-Efficiency Washing Machine Rebate Programs
- BMP 7: Public Information Programs
- BMP 8: School Education Programs
- BMP 9: Conservation Programs for Commercial, Industrial and Institutional (CII) Accounts
- BMP 10: Wholesale Agency Assistance Programs
- BMP 11: Conservation Pricing
- BMP 12: Conservation Coordinator
- BMP 13: Water Waste Prohibition
- BMP 14: Residential Ultra-low-flush-toilet Replacement Programs

For each BMP, the CUWCC defines the implementation conditions of programs, implementation schedules, coverage requirements, requirements for documenting BMP implementation, criteria to determine BMP implementation status and water savings assumptions. However, for some BMP's (i.e., BMP 7, BMP 8, BMP 10, BMP 11, BMP 12 and BMP 13), water savings are not quantified. Water savings estimates are reported (or can be converted) to a percentage reduction that can be achieved by implementing the BMP.

Each of the wholesale and retail water providers who are signatories to the MOU has biannual reporting requirements regarding the implementation status of each of the BMPs. The reporting requirements vary by BMP and generally require inputs regarding the implementation conditions and implementation status. These inputs allow the calculation of coverage factors for the BMP's (i.e., the percent of customer accounts impacted by the BMP).

It is expected that the DWR will have access to the data contained in the BMP Reporting Database and will be able to derive coverage factors for reporting agencies.

The estimated savings determined from the CUWCC database are water savings "to date" and do not represent future water savings from BMP implementation.

3.5 Water and Sewer Rates

The Department of Water Resources has a data file of water rates for 39 water utilities throughout California based on utility water rates posted on utility web-sites.

Black & Veatch conducts annual water rate surveys of water rates and wastewater rates for some water utilities in California.

Development of a comprehensive database of current and historical water rates among California utilities would be a resource intensive effort.

4.0 Identified Issues

There are a number of issues to be encountered in preparing water demand forecasts from existing water use and available demographic data. These issues are presented in light of the available data described above, and represent key considerations in the selection of a recommended methodology described below.

4.1 County Versus Planning Area Geographies

In general, an estimate of future water demand in a specific month of a given year and water use sector may be calculated by the equation:

$$Q_{c,m,y} = q_{c,m,y} \bullet N_{y,c}$$

where:

Q = total water use
q = per unit use
N = number of units
c = customer class
m = month
y = year

The units (N) must be consistent with the definition of units used in determining the per unit use (q) and secondly must have projected values in future years to base the forecast upon. The units are typically demographic units such as housing units, employment or population. The designated units can vary for different customer classes.

As noted above, demographic projections are developed at the county level rather than for planning areas. Thus, development of water demand forecasts by planning area may be achieved in one of two ways.

1. Estimate demand (Q_{county}) at the county level based on county level units (N_{county}) and then allocate from county demand (Q_{county}) to planning area demand ($Q_{planning\ area}$).
2. Allocate county level units (N_{county}) to planning area units ($N_{planning\ area}$) and then estimate planning area demand ($Q_{planning\ area}$).

Both of these approaches assume that the per unit use (q) can be estimated at the corresponding geographic level. Typically, the per unit use (q) value is determined for a sample of customers within the geography and assumed to be consistent with water use behavior throughout the geography.

4.2 Matching Water Use Account Data With Corresponding Demographic Data

As noted above, the units (N) must correspond with the unit defined in determining the per unit use rate (q). The PWSS data includes number of accounts for each customer class. However, demographic data are typically by population, housing units and employment. Within the single-family customer class, one account equates with one housing unit. However, in the multifamily class, one account could and typically is, associated with a number of housing units. Similarly, in the nonresidential classes one account is associated with a number of employees. Average ratios of the number of multifamily units per account, number of employees per commercial or industrial account, or the ratio of accounts per capita must be determined from available data for a given area.

Water use data may be converted from gallons per day per account to gallons per day per demographic unit prior to estimation of average rates of use (q). Alternatively, water demand can be estimated for the average rate per account (q) and the corresponding demographic data may be converted into estimated number of accounts (N) for each customer class.

4.3 Inclusion of Self-Supplied Users Into Forecast Demographics

As mentioned above, the per unit use (q) value is often determined for a sample of customers within the geography and assumed to be consistent with water use behavior throughout the geography. For example, the data within the PWSS database represents water use among a sample of utility-supplied water customers. The water demand forecast should represent the water demand of all municipal and industrial water users, including self-supplied residences and businesses. The utility level PWSS data can be used to derive average rates of use among utility-supplied customers.

The average rate of use among self-supplied users can be assumed to be the same as the average rate of use among utility-supplied users. Thus, the average rate of use (q) derived from the PWSS data may be multiplied by the county-level number of units (N) to estimate the county-level water demand (Q). Thus, all water users in the county are included in the water demand forecast. If (N) represents the number of units in the planning area, then the estimated (Q) is the planning area water demand.

In actuality, water use may be different between self-supplied and utility-supplied water users. For example, self-supplied users may not consider the cost of water in their water use behavior and self-supplied use may vary geographically due to well yield levels. However, there is insufficient data to address the differences in water use patterns among these two groups.

4.4 Factoring Conservation Effects at the Aggregate Level

Water conservation savings from implementation of BMPs as estimated from the CUWCC databases are at the utility level. Not all utilities are represented in the database as some utilities are non-signatories to the MOU and not all water users are served by utilities. Thus, implementation of BMPs as represented in the database is not comprehensive for a given county or planning area. The average reduction in water use from implementation of a BMP may be assumed for all users throughout the larger geography that implement the BMP. The implementation rate, or coverage, of a BMP throughout the larger geography can be assumed.

Coverage of a BMP may be determined for the signatory utilities reporting in the CUWCC database for a given county or planning area. A weighted average of the coverage rates of the reporting utilities within a county may be derived based on population served.

1. The weighted average of reporting utilities may be assumed for the entire county. This assumes that the non-signatory customers and self-supplied water users will implement a given BMP at the average rate of signatory customers within the same county.
2. A county weighted average can be derived in which the signatory coverage rates are weighted by corresponding population served and the coverage rate for the remaining county population is zero. This assumes that the non-signatory customers and self-supplied water users do not implement the given BMP.

5.0 Recommendations

The recommendations for water demand forecasting based upon the review of methodologies and data sources fall into two categories:
(1) recommendations for a methodology given currently available data and
(2) recommendations for future development. In addition, a methodology for estimating the impacts of water conservation efforts is recommended.

5.1 Recommendations Using Currently Available Data

It is recommended that the water demand forecast be developed using the Disaggregate Factor Forecast methodology as in section 2.1.2. This approach utilizes the existing PWSS database, although resources will need to be assigned to verification of the population served data for utilities reported within this database. In addition, this methodology allows for factors that affect water use to be included in the water demand model. Thus, alternative demand scenarios may be estimated given variation in the water demand factors.

Given the availability of demographic projections at the county level, it is recommended that the water demand forecast be developed at the county level. Furthermore, estimates of future water demand by county are more understandable to the general public than estimates of demand by planning area or other geographies. These county level estimates of future water demand may then be reallocated to planning area, or other, geographies as necessary.

The water conservation end-use model may be calibrated to the per unit use of each county by customer class and month. (See section 5.3.) Model parameters may be defined to reflect natural replacement rate of fixtures and the incremental implementation of BMPs. Average levels of BMP implementation may be derived from the CUWCC database. The end-use model will provide estimates of water conservation savings by customer class for each county for the planning horizon.

5.2 Recommendations for Future Development

It is recommended that development of the PWSS database be continued as a source of water use data for the state. In addition, it is recommended that water and sewer rate data be collected to correspond with the utilities and time periods reported in the PWSS database.

It is recommended that a database of per unit use derived from the PWSS data be established including corresponding municipal/local level data demographic, weather and rate data for the reporting utilities, years and months. Regression analysis of the data can produce explanatory water demand models for each customer class reported in the PWSS as described in section 2.1.3.

In addition, it is recommended that data be obtained to further refine the conservation assumptions used in development of estimated conservation savings at the county level (see section 5.1).

5.3 Recommendations for Estimating Conservation Savings

For the purpose of the CA-DWR statewide application, one methodology to be considered is a modified end-use approach. This would focus strictly on shifts of customers among the three water use efficiency classes and eliminate the use of the presence and intensity values (i.e., set values for U and A to one). The mechanical parameters should be set such that M_1 would represent current average water use in a specific end use and M_2 and M_3 would be based upon expected reductions in the average water use given the implementation of passive or active conservation measures. The saturation levels, S values, could be used to represent the coverage or market penetration of given conservation measures.

For forecasting purposes, it should be noted that baseline conditions would reflect conservation activities that have been implemented to date. Forecasts of water use given passive and active conservation would reflect conservation activities projected to be implemented throughout the planning horizon. Estimation of conservation effects through the application of the end-use model will require calibration of end-use model inputs for each end use within a given customer class and for each month, for each location such that the sum of the end-use water demands are equal to the per unit use (q) from the forecast methodology. This approach incorporates the current level of conservation effort into the baseline demand forecast in that the baseline per unit use (q) reflects the impact of current BMPs. Thus, conservation water savings estimated in future years by the end-use model reflect the additional water savings to be achieved from both active and passive conservation. For this reason, the coverage factors represented in the end-use model representing implementation of BMPs should reflect the incremental, or additional, coverage of BMPs in future years.

The first step of the end-use application will be the definition of end uses to be addressed. It is recommended that the following be considered for residential customer classes:

- Toilets
- Showers
- Faucets
- Dishwashers
- Washing machines
- Dishwashers
- Other indoor
- Landscape irrigation
- Other outdoor

For defined nonresidential customer classes, the following end uses should be considered:

- Toilets
- Other indoor uses
- Outdoor uses

The next step will be to set the mechanical parameters to represent the average quantities of water use per accounting unit (per average account). The M_1 category can be defined as the current average water use per end use, with subsequent categories (M_2 and M_3) defined as average water use per end use given an expected water use reduction from a shift in the efficiency class (resulting from passive or active conservation measure).

Execution of this step will require the determination of default water usage by end uses for the selected customer classes. There are a number of available resources for determining water use by end use. The American Water Works Association Research Foundation (AWWARF) *Residential End Uses of Water* (1999) provides an excellent examination of how water is used for various purposes in the single-family residential sector. Of twelve study sites on the study, four were from California. Raw data for these study areas are available from AWWARF. The AWWARF *Commercial and Institutional End Uses of Water* (2000) provides useful insights into selected CI customer groups. There are also a number of water use and conservation baseline studies conducted in the State of California that would provide beneficial information regarding fixture characteristics and water use at the end use level, including studies conducted for the Marin Municipal Water District, the City of San Jose, the East Bay Municipal Utility District and the Santa Clara Valley Water District. It is expected that similar studies have been conducted at other agencies in California.

For both the residential and nonresidential sector, it would be helpful to conduct an analysis of aggregate monthly water use patterns to estimate a percentage of indoor and outdoor water use. Average water use rates per account for study areas may be determined through the analysis of the PWSS data. A minimum month analysis may be used to estimate the breakout of seasonal and nonseasonal water use components. With the minimum-month method, the percent of annual use in a given year that is considered seasonal is calculated as:

$$S_p = 1 - (M_p * 12)$$

where:

S_p = percent of annual use that is seasonal

M_p = percent of annual use during the minimum month

This approach should be modified for agencies that use bimonthly or quarterly billing cycles. Caution should be used in interpreting seasonal water use to represent outdoor use, as some uses may be seasonal in nature, but not necessarily outdoor use. Alternately, some outdoor uses may not be seasonal in nature. However, this method may provide a reasonable estimate of indoor and outdoor water use components.

Once the base, M_1, average use rates are determined for each customer class, the average rate of water use must be calibrated to equal the per unit use (q) from the forecast methodology. Subsequently, M_2 and M_3 for specific end uses would be based upon expected reductions in the average water use given the implementation of passive or active conservation measures. The expected water use reductions as reported by the CUWCC for BMPs (specifically BMP 1, BMP 2, BMP 3, BMP 4, BMP 5, BMP 6, BMP 9 and BMP 14) can be used subsequently to set the water use rates for the M_2 and M_3 parameters. Potential water savings for some of the BMPs will be unquantifiable (BMP 7, BMP 8, BMP 10, BMP 12 and BMP 13) as these are generally education and assistance programs. The BMP 11, water conservation pricing, can be addressed through the forecasting methodology to the extent that pricing is included in the models.

The saturation levels, S values, for each end use could be used to represent the coverage or market penetration of given conservation measures. The CUWCC BMP reporting database will be a valuable resource for determining the market saturation, or coverage, of BMPs by reporting unit. Coverage of a BMP may be determined for the signatory utilities reporting in the CUWCC database for a given county or planning area. As indicated earlier, a weighted average of the coverage rates of the reporting utilities within a county may be derived based on population served. The coverage factors represented in the end-use model representing implementation of BMPs should reflect the incremental, or additional, coverage of BMPs in future years.

Water savings from both passive (i.e., naturally occurring) and active conservation can be estimated for future years. These estimated water savings represent a scenario of full implementation of BMPs. The baseline forecast (i.e., the forecast proposed by either section 5.1 or 5.2) reflects the continuation of the current level of water conservation effort and incorporates partial implementation of many of the BMPs.